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VARIABILITY OF ANNUAL PRECIPITATION IN CANADA

RICHMOND W. LONGLEY

Meteorology Section, Suffield Experimental Station, Ralston, Alberta

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ABSTRACT

From computed values of the coefficient of variation of precipitation for Canada and northern United States, the distribution of this variable across Canada is determined. The minimum variability increases as one moves poleward. Also the variability is great in the central prairies. The pattern among the mountains and valleys of British Columbia is irregular.

INTRODUCTION

In the study of the rainfall of a district the two most important features are the average for the year and the normal variation through the year. The variation from one year to another is also very important but one on which little work has been done. This variation determines the types of industry that can thrive in the vicinity. If the industry is such that it needs each year the median rainfall or more for success, it will have difficulty in one year out of two. Another industry which demands only the amount given by the first quartile will have sufficient moisture three years out of four.

RESULTS OF PREVIOUS STUDIES

The only previous attempt to determine the distribution of the variation of precipitation in Canada was made by Taylor [1]. His work was based on only 30 stations. He states that in most cases the annual rainfalls for 20 years since 1900 were used.

Before proceeding with a more complete study of the variation, it was felt that an analysis of the different measures was necessary in order to determine their limitations and to select the best. This earlier study was reported by Longley [2]. As a result of this study which considered the advantages and disadvantages of different measures of variability, it was decided that the measure to be used was the coefficient of variation, v_σ, i. e., the standard deviation divided by the mean. In most previous studies, including the one by Taylor, the measure used was the relative variability, v_r, i. e., the mean deviation divided by the mean. Since approximately $v_r=\frac{4}{5}\,v_\sigma$ the results obtained may be compared with previous studies if it is desired.

Another result from the previous study was the decision to limit the calculation of v_σ to those stations where 35 years of data were available, or, in districts where such stations were not available, to use no station which had less than 30 years of record. For shorter records, the variation because of the error of sampling was too great to consider the values reliable.

DATA USED

After the measure and the minimum length of record to be used were determined, the value of v_σ was computed for 142 Canadian stations and 34 stations from the neighboring States of the United States. The data for the Canadian stations were obtained from the published and unpublished records of the Meteorological Service of Canada. Records for every available year to 1950 were used. The data from the United States were obtained from the "Local Climatological Summaries with Comparative Data" published under the direction of the United States Weather Bureau. Data used covered the period 1900–1950.

The data for British Columbia and Washington have already been used in the study by Longley. In that report there was an error which was brought to the author's attention by Mr. Philip Williams, U. S. Weather Bureau, Salt Lake City, Utah. The mean annual precipitation at Tatoosh Island should be 74.88 inches, not 30.64, and coefficient of variability 14.8, not 36.2. This change will also cause a change in the isolines of figure 2 of that study, and give a distribution as shown in figure 1 of this report.

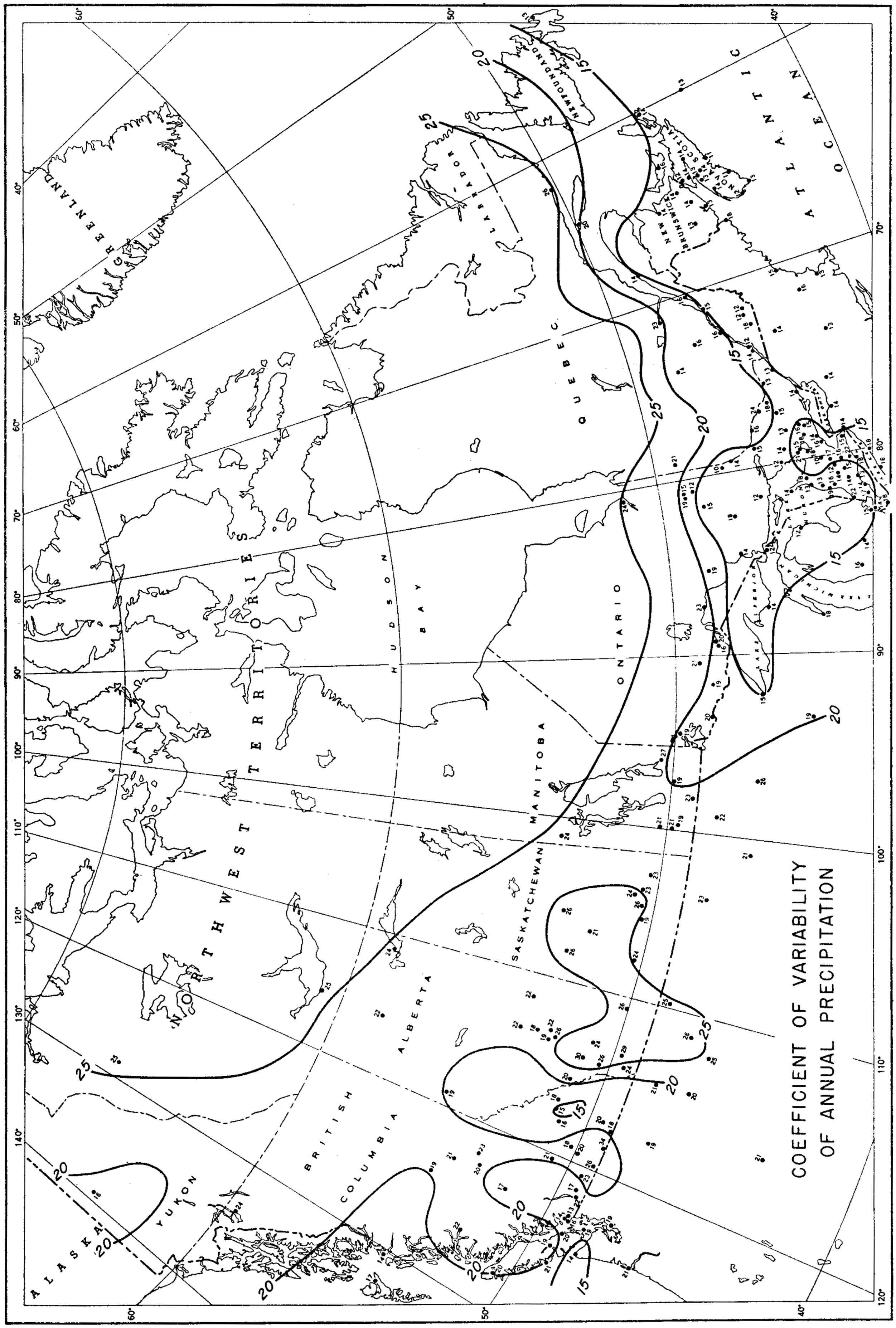

FIGURE 1.—Coefficient of variation (v_r, percent) of annual precipitation in Canada.

TABLE 1.—*Mean, standard deviation, and coefficient of variation of annual precipitation in Canada and northern United States*

Station	Number of years	Mean precipitation (in.)	Standard deviation (in.)	Coefficient of variation (percent)
British Columbia				
Agassiz	57	58.68	12.70	22
Alberni	48	66.50	12.36	19
Atlin	31	10.99	2.70	24
Barkerville	56	40.21	9.37	23
Bella Coola	45	54.90	11.90	22
Big Creek	42	12.27	2.11	17
Clayoquot	41	106.3	22.24	21
Fort St. James	55	15.62	3.02	19
Garry Point	48	36.46	5.87	16
Glacier	38	56.90	8.39	15
Golden	35	18.31	3.20	18
Greenwood	35	17.04	5.77	34
Hedley	39	11.45	2.96	26
Hope	36	56.39	9.72	17
Kamloops	55	10.21	2.18	21
Kelowna	46	12.22	2.40	20
Masset	46	55.17	9.38	17
Nanaimo	49	37.91	7.75	20
Nelson	44	26.32	5.34	20
New Westminster	68	57.06	7.47	13
Prince George	33	22.31	4.61	21
Prince Rupert	36	93.88	13.54	14
Princeton	53	13.17	3.01	23
Quatsino	46	92.74	18.55	20
Quesnel	46	16.88	3.46	20
Revelstoke	32	39.43	6.44	16
Rossland	38	29.08	5.32	18
Vancouver	42	58.02	8.12	14
Vernon	48	14.80	2.70	18
Victoria	52	26.90	5.09	19
Yukon				
Dawson	49	12.81	2.12	16
Northwest Territories				
Fort Good Hope	42	11.62	2.93	25
Hay River	37	11.68	2.93	25
Alberta				
Alix	38	16.15	3.62	22
Banff	55	18.86	3.80	20
Beaverlodge	30	17.29	3.33	19
Calgary	66	16.70	4.98	30
Edmonton	68	17.46	3.79	22
Fort Chipewyan	30	11.85	2.80	24
Fort Vermilion	39	12.05	2.71	22
Gleichen	37	14.72	3.48	24
Hillsdown	43	17.22	4.48	26
Lacombe	41	17.74	3.45	19
Macleod	59	14.89	4.38	29
Medicine Hat	67	12.91	3.40	26
Pekisko	30	24.17	6.28	26
Pincher Creek	40	20.35	4.90	24
Ranfurly	46	17.70	3.92	22
Wetaskawin	37	17.43	3.12	18
Saskatchewan				
Battleford	60	13.35	3.52	26
Grenfell	44	17.79	4.05	23
Indian Head	53	17.28	3.90	23
Moose Jaw	42	14.82	2.78	19
Prince Albert	66	15.73	4.09	26
Qu'Appelle	67	18.32	4.39	24
Regina	62	14.37	3.80	26
Saskatoon	44	14.43	3.08	21
Swift Current	65	15.04	3.56	24
Manitoba				
Brandon	59	18.11	3.73	21
Minnedosa	68	17.29	3.62	21
Morden	64	19.08	4.35	23
Pinawa	33	15.18	4.05	27
The Pas	38	16.71	3.98	24
Treesbank	51	18.29	3.52	19
Winnipeg	79	20.83	3.91	19
Ontario				
Agincourt	53	30.44	4.27	14
Alton	49	32.89	3.46	10
Barrie	44	31.70	5.69	18
Beatrice	74	40.88	5.61	14
Biscotasing	38	28.66	5.11	18
Brantford	47	30.54	4.83	16
Brucefield	44	33.16	5.31	16
Chatham	59	29.28	4.93	17
Clontarf	57	30.80	4.67	15
Cochrane	33	30.56	5.75	19
Coldwater	37	34.69	7.41	21
Fort Francis	33	27.05	5.39	20
Goderich	71	30.54	5.93	19
Guelph	59	29.89	5.03	17
Haileybury	46	31.40	3.22	10

TABLE 1.—*Mean, standard deviation, and coefficient of variation of annual precipitation in Canada and northern United States*—Con.

Station	Number of years	Mean precipitation (in.)	Standard deviation (in.)	Coefficient of variation (percent)
Ontario—Continued				
Haliburton	35	33.33	4.28	13
Iroquois Falls	34	33.03	4.03	12
Kakabeka Falls	41	26.92	4.35	16
Kenora	44	25.23	4.72	19
Kingston	77	33.10	4.74	14
Lakefield	47	28.71	4.71	16
Lindsay	68	33.13	5.84	18
London	66	38.24	5.30	14
Lucknow	63	36.90	4.88	13
Mine Centre	33	27.26	5.19	19
Montreal River	40	32.20	4.58	14
Moosonee	31	26.50	6.34	24
Morrisburg	35	38.93	5.00	13
Orillia	57	32.80	4.97	15
Ottawa	77	34.12	4.42	13
Owen Sound	56	36.09	6.45	18
Paris	61	34.66	4.18	12
Parry Sound	76	38.63	4.84	12
Pelee Island	36	29.94	5.41	18
Pembroke	51	31.83	7.48	24
Peterborough	75	30.77	4.51	15
Port Arthur	73	24.91	4.88	20
Port Dover	64	33.16	6.14	18
Port Stanley	51	35.13	4.48	13
Renfrew	57	27.76	4.96	18
Ridgetown	41	33.33	4.50	14
Rutherglen	35	30.56	4.69	15
Savanne	40	26.05	5.39	21
Schreiber	38	29.74	6.83	23
Simcoe	48	34.73	7.67	22
Southampton	77	35.24	4.69	13
Stonecliff	36	28.34	4.64	16
Stratford	83	38.07	5.18	14
Tobermory	32	32.50	4.46	14
Toronto	106	32.20	5.05	16
Turbine	34	32.06	3.92	12
Wallaceburg	32	28.56	6.20	22
Wawaitin Falls	33	30.86	4.66	15
Welland	60	34.12	5.26	15
White River	60	28.30	5.32	19
Windsor	53	31.71	4.37	14
Woodstock	76	32.66	4.81	15
Quebec				
Abitibi	38	26.82	5.57	21
Anticosti	66	31.23	6.29	20
Brome	58	39.34	7.34	18
Chicoutimi	50	30.66	6.94	23
Father Point	74	33.50	4.84	14
Gouin Dam	35	38.27	5.22	14
La Tuque	35	33.56	5.51	16
Lennoxville	35	40.07	4.90	12
Montreal	79	41.07	4.96	12
Natashquan	29	36.12	9.02	26
Quebec	80	37.76	5.71	15
Ste. Anne de Bellevue	33	38.17	5.18	14
Ste. Anne de la Pocatiere	35	37.30	5.80	16
Shawinigan Falls	41	36.30	5.76	16
Sherbrooke	47	38.50	4.74	12
New Brunswick				
Chatham	77	39.86	5.80	14
Fredericton	74	42.08	5.63	13
Moncton	50	36.96	5.27	14
Saint John	79	46.59	6.06	13
Sussex	50	39.42	5.46	14
Nova Scotia				
Annapolis Royal	33	41.41	6.01	14
Halifax	77	55.61	6.31	11
Kentville	37	40.82	5.56	13
Liverpool	37	57.72	6.33	11
Nappan	37	38.23	4.54	12
Parrsboro	41	42.84	6.19	14
Sable Island	53	50.16	6.59	13
Sydney	78	50.72	6.83	14
Truro	56	41.36	5.91	14
Windsor	37	39.80	5.58	14
Wolfville	45	39.97	5.33	13
Yarmouth	70	51.50	6.00	12
Prince Edward Island				
Charlottetown	75	40.27	6.48	16
Newfoundland				
St. John's	65	53.96	7.08	13
United States				
Albany, N. Y.	51	33.17	4.31	13
Alpena, Mich.	51	26.66	3.18	12
Bismarck, N. Dak.	51	15.71	3.32	21

TABLE 1.—*Mean, standard deviation, and coefficient of variation of annual precipitation in Canada and northern United States*—Con.

Station	Number of years	Mean precipitation (in.)	Standard deviation (in.)	Coefficient of variation (percent)
United States—Continued				
Boise, Idaho	51	12.17	2.50	21
Boston, Mass	51	38.54	5.11	13
Burlington, Vt	51	31.87	4.55	14
Buffalo, N. Y	51	33.26	4.71	14
Cleveland, Ohio	51	32.76	5.73	18
Concord, N. H	51	36.42	5.93	16
Detroit, Mich	51	31.44	4.67	15
Devil's Lake, N. Dak	46	17.33	3.84	22
Duluth, Minn	51	26.67	3.89	15
Eastport, Maine	51	36.22	6.42	18
Erie, Pa	51	35.66	6.42	18
Fargo, N. Dak	51	20.78	5.34	26
Grand Rapids, Mich	51	32.19	5.26	16
Great Falls, Mont	51	14.97	3.93	26
Green Bay, Wis	51	26.89	4.70	18
Havre, Mont	51	12.65	3.19	25
Helena, Mont	51	12.29	3.13	25
Kalispell, Mont	52	14.86	3.16	21
Lansing, Mich	51	31.36	4.40	14
Marquette, Mich	51	31.81	4.44	14
Minneapolis, Minn	51	26.79	5.16	19
Missoula, Mont	50	13.76	2.72	20
North Head, Wash	51	54.38	11.18	21
Portland, Maine	51	41.52	6.39	15
Rochester, N. Y	51	31.87	4.30	14
Sault Ste. Marie, Mich	51	29.26	3.67	12
Seattle, Wash	51	32.15	6.21	19
Spokane, Wash	51	15.05	2.87	19
Syracuse, N. Y	48	35.54	4.89	14
Tatoosh Island, Wash	48	74.88	11.08	14
Williston, N. Dak	51	14.36	3.29	23

Unfortunately, the 142 Canadian stations were not distributed uniformly. Over one-third were in Ontario, and there were only two in the Northwest Territories. Also there were only two in Ontario and Quebec north of the 50° parallel. This distribution reflects the interest in the weather early in the century, for a station must have been established before 1920 to be included in this study.

The values for v_σ for the different stations are given to the nearest percent in table 1 and are plotted on figure 1. Isolines are drawn for as much of Canada as it was thought the data justified.

ANALYSIS OF RESULTS

One of the first conclusions in examining the results is that the data are very irregular. From the meteorological point of view, the variation for southern Ontario should not be great, for the same storms sweep over all stations. The adjacent lakes do cause small differences in rainfall, but most of the area has an annual precipitation between 30 and 35 inches. Yet in a line from Simcoe on Lake Erie to Coldwater on Georgian Bay, there is the following succession of values: 18, 22, 14, 12, 17, 10, 18, 15, and 21. Again in the Minnesota-North Dakota region, Fargo, N.Dak., with a value of 26 for v_σ is surrounded by values of 19, 15, 22, and 21, with the data taken for the same period of 51 years.

One cause for irregularity is inconsistent and, at times, careless observing. The data from Sable Island give one example. $v_\sigma = 13.5$ for a period of 53 years. The results for two years were discarded since the results were considered unreliable because of a leaky rain gage. Had these been included the value of v_σ would have been 18.8, five percentage points greater.

There must be other courses, at present obscure, for the change in v_σ from place to place. Lucknow, Goderich, and Southampton, Ontario, are located within a small radius and all have records over 60 years in length. Yet the values of v_σ are respectively 13.2, 19.4, and 13.3. It is possible that in British Columbia the movement of a station from one location to another might influence the result. But in southern Ontario, where the precipitation is so uniform, a transfer over a short distance should not cause a serious break in the record.

In spite of the irregular spatial variation in v_σ noted above, there is found a broad over-all picture of the change across Canada. The region where the variation is least is found in the Maritime Provinces of eastern Canada. There v_σ is about $\frac{1}{8}$. In other words, the total precipitation for the year is found two out of three times between $\frac{7}{8}$M and $\frac{9}{8}$M, where M is the mean. This assumes that the distribution is approximately normal. The isoline for 15 percent extends from this district westward to include much of tha area about the Great Lakes. This district from the Great Lakes eastward is in the track of the major storms of the continent. The Mississippi Valley storms usually hit the whole area. The storms along the east coast of the United States pass over the Maritime Provinces, bringing frequent rains.

Although the British Columbia coast gets more precipitation than eastern Canada, the variability is greater. At a few stations it is below 15 percent but most of the coastal regions have a variability between 15 and 20 percent.

There are two areas where the value of v_σ is over 25 percent. That means approximately that in two out of three years the annual rainfall lies between $\frac{3}{4}$ M and $\frac{5}{4}$ M. One of these areas lies along the Mackenzie River. On the map the 25 percent isoline is drawn across the map from Belle Isle, Newfoundland, to near Moosonee, and then across Ontario and Manitoba to Great Slave Lake. On the basis of the available evidence this may be right. We need further data to confirm this. The second district extends along the South Saskatchewan, and into central Montana. A further investigation is necessary to explain why this area has a greater variability of precipitation than the areas on all sides.

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